Claims

1. A pupilometer comprising image capturing means, illumination means comprising two spaced apart light sources, stimulation means, and image processing software, wherein said illumination means generates and emits light of a first wave-length, and said stimulation means generates and emits light of a second wavelength, and wherein said illumination means is arranged to one or both sides of said image capturing means and, in use, shines light towards the eyeball, wherein the said image processing software receives data from the image capturing means, and by processing said data according to an algorithm establishes the distance between the surface of the eyeball and the camera.

2. A pupilometer according to Claim 1, wherein the step of establishing the distance between the surface of the eyeball and the camera includes finding highlights on the surface of the eyeball generated by the said illumination means and calculating the distance between said highlights.

3. A pupilometer according to Claim 1 or 2, wherein the wavelength of the light generated by said illumination means is in the infra-red spectrum.

4. A pupilometer according to Claim 3, wherein each light source is an infra-red light emitting diode.

5. A pupilometer according to any preceding claim, wherein the image capturing means has an optical axis, and wherein the said two spaced apart light sources shine light in a direction substantially parallel to the optical axis of the said image capturing means.

6. A pupilometer according to any preceding claim, wherein said stimulation means comprises a light emitting diode generating and emitting light in the visible spectrum.

7. A pupilometer according to any preceding claim, wherein said image capturing means comprises a camera.

8. A pupilometer according to any preceding claim, further comprising an optical filter mounted on the [camera] image capturing means.

9. A pupilometer according to Claim 8, wherein the optical filter passes only light of the said first-wavelength.

10. A pupilometer according to Claim 7 to 9, wherein said camera generates a video signal.

11. A pupilometer according to any of Claims 7 to 10, wherein said camera is a complementary metal oxide semiconductor device.

12. A pupilometer according to any preceding claim, wherein said image detection means further includes a micro-controller including a micro-processor.

13. A pupilometer according to any preceding claim, further comprising an analogue to digital converter arranged between said camera and said micro-controller.

14. A pupilometer according to any preceding claim, further comprising memory means.

15. A pupilometer according to any preceding claim, further comprising data input means and display means.

16. A pupilometer according to any preceding claim, further comprising an interface for linking said pupilometer to an external computer.

17. A pupilometer according to any preceding claim, wherein said pupilometer is a hand-held device, wherein said hand held device mounts, said image capturing means, illumination means, stimulation means, image processing software, data input means, display means, a computer interface, said hand-held device including a hand grip.

18. A pupilometer according to Claim 18, wherein, in use the user views the image of the eye displayed on the display means, the said image having been captured by said capture means and processed by said image processing software.

19. A pupilometer according to Claim 15 or 16, further comprising a power supply consisting of a battery.

20. A pupilometer according to any preceding claim, wherein said image processing software includes an algorithm, wherein said algorithm:

i) commands the illuminating means to illuminate an eye;

ii) detects the pupil within the image of the eye;

iii) measures the size of the detected pupil;

iv) establishes the distance of the from the camera to the eye;

v) stimulates a pupil reflex action; and

vi) measures the pupil reflex action.

21. A pupilometer according to Claim 20, wherein the step of detecting the pupil within the image of the eye consists of acquiring image data in the form of a two-dimensional array of values, each value representing the greyscale intensity of an image pixel, and processing said image data according to the following sub-steps:

i) Read the image data into a program;

ii) Run the program to identify the darkest pixel;

iii) Calculate a threshold value as a function of the darkness of the darkest pixel;

iv) Identify and store all pixels as dark or darker than the threshold value as of the pupil class;

v) Calculate the edge value across each pixel in the pupil class;

vi) Establish an edge value threshold value, wherein all image pixels with an edge value greater than or equal to the threshold are identified and stored as pupil edge class;

vii) Execute a search of the image to locate the first pixel in the pupil edge class and assume that this pixel lies on the pupil boundary;

viii) Run an algorithm to connect adjoining pupil edge pixels;

ix) Calculate the rectangular dimension of the pupil region, and fit an ellipse consisting of n points inside the rectangle;

x) If more than n/c (where c is a nominal value) of said n points coincide with a pupil edge pixel classify the region as the pupil and if less than n/c re-start the search with a new image; and

xi) Record pupil radius as the maximum radius of the ellipse.

22. A pupilometer according to Claim 21, wherein said program is a Delphi program.

23. A pupilometer according to Claim 21 or 22, wherein the said edge value is calculated according to a gradient algorithm, wherein the gradient algorithm provides that the gross radial gradient (G) across a central pixel P_4 in an eight pixel array equals $|P4-P0|+|P4-P1|+|P4-P2|+|P4-P5|+|P4-P8|+|P4-P7|+|P4-P6|+|P4-P3|=G$, and wherein the edge value threshold is a function of G the gross radial gradient.

24. A pupilometer according to any of Claims 21 to 23, wherein said search of the image to locate the first pixel in the pupil edge class is a spiral search from the centre of the image.

25. A pupilometer according to any of Claims 21 to 24, wherein said algorithm is a recursive flood fill algorithm.

26. A pupilometer according to any of Claims 21 to 25, wherein n equals 32.

27. A pupilometer according to any of Claims 21 to 26, wherein c equals 2.

28. A pupilometer according to any of Claims 21 to 27, wherein the step of establishing the distance of the pupilometer from the eye includes identifying highlights resulting from the illumination means by the following steps:

i) scan the image for the brightest pixel;

ii) re-scan the image and mark those pixels with a value greater than the brightest eight as highlight pixels;

iii) Record the extents of the highlight pixels in the x and y directions;

iv) Calculate the centre of the extents;

v) Perform a search of the highlight extents until a highlight pixel is found;

vi) Flood-fill the area around the highlight pixel and calculate the centre of the fill area.

vii) Repeat steps v and vi for the other side of the highlight extents

viii) Calculate the horizontal distance between the centres of the highlight areas and store said value as a range value.

29. A pupilometer according to Claim 28, wherein the said search of the highlight extents consists the following step:

i) Perform from the centre of the extents a multi-pass expanding search of one side of the highlight extents until a highlight pixel is found.

30. A pupilometer according to any of Claims 21 to 27, wherein the step of establishing the distance of the pupilometer from the eye includes identifying highlights resulting from the illumination means by the following steps:

i) scan pixels centred around the pupil for pixels with a brightness value greater than a threshold value;

ii) classify all pixels with a brightness value greater than the threshold as Highlight_Test pixels;

iii) flood fill pixels adjoining the Highlight_Test pixels and record number of pixels and the co-ordinates of the fill area;

iv) designate the areas from step iii as possible highlights;

v) compare the vertical positions of all possible identified highlight areas and identify the two highlight areas having the closest vertical alignment;

vi) compare the number of pixels in the two highlight areas having the closest vertical alignment, and the number of pixels spacing the highlight areas aligned vertically most closely;

vii) if the difference in the number of pixels in the two highlight areas having the closest vertical alignment is not greater than a threshold value, and the number of pixels vertically spacing the two highlight areas is not greater than another threshold value, classify the two highlight areas as highlights;

viii) calculate the horizontal distance between the centres of the highlight areas and store said value as a range value.

31. A pupilometer according to any preceding claim, wherein stimulation of a pupil reflex reaction comprises the following steps:

i) establish absolute pupil diameter using the measures of pupil diameter and range;

ii) commence a stimulation cycle by stimulating the pupil with a bright light source for a time period;

iii) record a pupil constriction response curve during and after said stimulus;

iv) display pupil constriction response curve on said display.

32. A pupilometer according to any preceding claim, wherein the absolute pupil diameter is established by reference to a look-up table.

33. A pupilometer according to any preceding claims, wherein said bright light source is a bright white light source.

34. Image processing software comprising computer program instructions for causing a computer to perform the algorithm steps set out in any of Claims 20 to 32.

35. A process for obtaining pupil image information comprising the steps of:

i) Illuminating a pupil with the illumination means of a pupilometer according to any of Claims 1 to 33; and

ii) Running image processing software according to Claim 34.

36. A hand-held pupilometer comprising image capturing means, illumination means, stimulation means, image processing software, a hand-grip, a display, and command means, wherein said illumination means generates and emits light of a first wave-length, and said stimulation means generates and emits light of a second wavelength, and wherein said illumination means, in use, shines light towards the eyeball, the user viewing an image of the eye displayed on the display means, the said image having been captured by said capture means and processed by said image processing software.

37. A pupilometer substantially as shown in, and as described with reference to, the drawings.